Spatial Beamforming.

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CE08555R

A METHOD AND APPARATUS FOR ANTENNA ARRAY BEAMFORMING

Field of the Invention

The present invention relates to wireless telecommunication systems, and more particularly to the use of antenna arrays in wireless telecommunication systems.

Background of the Invention

An important goal in designing a wireless communication system is to maximize system capacity, that is, to maximize a number of users that may simultaneously be served by the communication system. One way of increasing system capacity is to lower the transmit power allocated to each user. By lowering the allocated transmit power, interference for all users is lowered, which allows for the addition of new users to the system.

One way to lower the transmit power allocated to each user, or subscriber unit, is to increase the efficiency of the wireless link, or communication channel, between the subscriber unit and the base station serving that user. One method of increasing the efficiency of the link is to broadcast information to a target subscriber unit using a transmit antenna diversity system. A transmit antenna diversity system allows the transmitted signal to be beamformed so that a narrower, more focused beam is transmitted to the user. Antenna beamforming allows for a base station to lower the transmit power allocated to the signal, since the allocated power is less widely dispersed. Antenna beamforming also reduces multipath fading of the transmitted signal and interference with non-targeted users since the beam is more narrowly focused.

One method of antenna beamforming involves two-antenna diversity. Two-antenna diversity uses an antenna array consisting of two antennas, or array elements, to transmit a signal and then applies an optimization technique to improve the quality of the transmitted signal over the performance that would be afforded by the use of a single antenna. One of the simplest forms of two-antenna diversity is two-antenna selection transmit diversity (STD). As its name implies, this method involves selecting one of two

antennas as the antenna that will be utilized as the transmitter for a particular communication. A typical method of selecting an antenna involves choosing the antenna that has the highest received power with respect to training, synchronization, or data communications exchanged with the target subscriber unit.

Another method of antenna beamforming involves separately weighting the signal transmitted by each element of the antenna array. If the elements of the antenna array are weighted and phased appropriately, the signals broadcast from these elements will add constructively at a receiver of the target subscriber unit. However, two conditions must be met before an optimal weighting can be applied to the transmit array. First, the channel between each of the array elements and the subscriber of interest must be known. Secondly, it must be possible to compute the signal-to-noise ratio of the subscriber unit of interest.

Previous work has been performed on optimizing the weightings determined at an antenna array for each of multiple subscribers units. Current methods for weighting the coefficients (hereinafter referred to as "TxAA") are optimal only if the interference environment of the target subscriber unit is dominated by inter-cell interference (optimal in the sense of maximizing the signal-to-noise ratio at the subscriber unit for a given level of transmit power). However, in many applications, especially data applications, the target subscriber unit is close to the base station, where self-interference is the dominant source of interference. In these conditions, the existing method for optimizing the transmitter weighting coefficients can be highly non-optimal.

In addition, current methods for weighting the coefficients do not account for the self-interference introduced by multipath delay. In fact, the current method is optimal only if one of the following two conditions hold: (i) the propagation channel has only a single path, or (ii) the ratio of intra-cell interference power to inter-cell interference power is zero. The latter condition can never be met precisely, but may be an acceptable approximation in some circumstances. In the absence of conditions (i) or (ii), situations arise where the current methods for weighting the perform worse than a much simpler selection transmit diversity (STD) weighting system.

As a result, current methods for weighting the coefficients are less than optimal for many operating environments. Therefore, an antenna array beamforming technique is needed that optimizes performance of an antenna array in a high multipath fading environment or in environments of significant self-interference or where intra-cell interference dominates inter-cell interference.

Brief Description of the Drawings

FIG. 1 is a block diagram of a communication system in accordance with an embodiment of the present invention.

FIG. 2 is a block diagram of a transmitting communication device in accordance with an embodiment of the present invention.

FIG. 3 is a block diagram of multiple transmitted signal paths of a transmitting communication device in accordance with an embodiment of the present invention.

FIG. 4 is a logic flow diagram of antenna beamforming steps executed by a transmitting communication device in accordance with an embodiment of the present invention.

FIG. 5 is a table comparing the signal-to-noise ratio at the output of a matched-filter receiver for a signal transmitted by an antenna array employing the current coefficient weighting system and employing a selection transmit diversity system.

FIG. 6 is a table comparing the output of the matched-filter receiver for a signal received from a transmitting communication device employing the current coefficient weighting system and for a transmitting communication device employing optimized transmitting antenna array weighting determined in accordance with an embodiment of the present invention.

Detailed Description of the Invention

In order to optimize performance of an antenna array in a high multipath fading environment or in environments of significant self-interference or where intra-cell interference dominates inter-cell interference, an antenna array beamforming technique employs independent transmit weighting coefficients for multiple subscriber units served by a transmitting communication device. Optimization of the weighting coefficients is a joint, rather than an independent, venture of the multiple subscriber units. Joint optimization ~~preferably is implemented at the transmitting~~ communication device and involves the communication device optimizing based on knowledge of the channels between itself and each of the subscriber units, as well knowledge of the inter-cell and intra-cell interference observed at each of the subscriber units. Joint optimization of the weighting coefficients is a complex process, and to simplify the process optimization criteria are defined that allow the weighting coefficients corresponding to the subscriber units to be optimized independently rather than jointly. Because this technique accounts for self-interference, it yields a weighting that is more nearly optimal than the current methods of transmit antenna array weighting

The present invention may be more fully described with reference to FIGS. 1-X. FIG. 1 is a block diagram of a wireless communication system 100 in accordance with an embodiment of the present invention. Preferably communication system 100 is a code division multiple access (CDMA) communication system that includes multiple ("K") orthogonal communication channels, although those who are of ordinary skill in the art realize that that the present invention may be utilized in any wireless communication system, such as a time division multiple access (TDMA) communication system or an orthogonal frequency division multiplexing (OFDM) communication system. Preferably, each communication channel comprises one of multiple orthogonal spreading codes, such as Pseudo-noise (PN) sequences such as Walsh codes. The use of spreading codes permits the coexistence of multiple communication channels in the same frequency bandwidth.

Communication system 100 includes multiple geographically-diverse base stations 101-103 (three shown). Each base station 101-103 provides communication service to a respective service coverage area, or cell, 111-113. Each base station 101-103 preferably